P1.6

GREAT LAKES WINTERTIME MESOVORTICES AND THE EXAMPLE OF FEBRUARY 20, 2008

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Abstract

The mesoscale vortices that occasionally form over the Great Lakes during winter are interesting local features that may develop during a northerly flow of cold, dry Arctic air over the relatively warm and ice-free lake surfaces. These phenomena result from the unique combinations of local mesoscale meteorological processes including diabatic heating from the lake surfaces causing the formation of low-level clouds; organized convergence over the lakes of thermally driven land breezes created by the strong temperature contrast between the cold, snow covered land surfaces and the warm, ice free lake surfaces; low-level cyclonic rotation imparted to the clouds by the concave shape of the lakeshore; mid-level subsidence with a low-level subsidence inversion high enough to allow a sufficient depth for the unstable mixing layer above the lake surface; and synoptic-scale winds light enough to avoid disrupting formation of the developing circulation above the lake surface.

This case study examines the features that contributed to the striking image on visible satellite imagery of the rare appearance of two mesocyclones simultaneously on Lakes Huron and Michigan during February 20, 2008.

Overview of Poster

The images below show mesocyclones over the southern sections of Lakes Michigan and Huron. These very interesting examples of air-lake interaction are useful for examining some factors relevant to, and required for, the formation of the lake mesocyclones.

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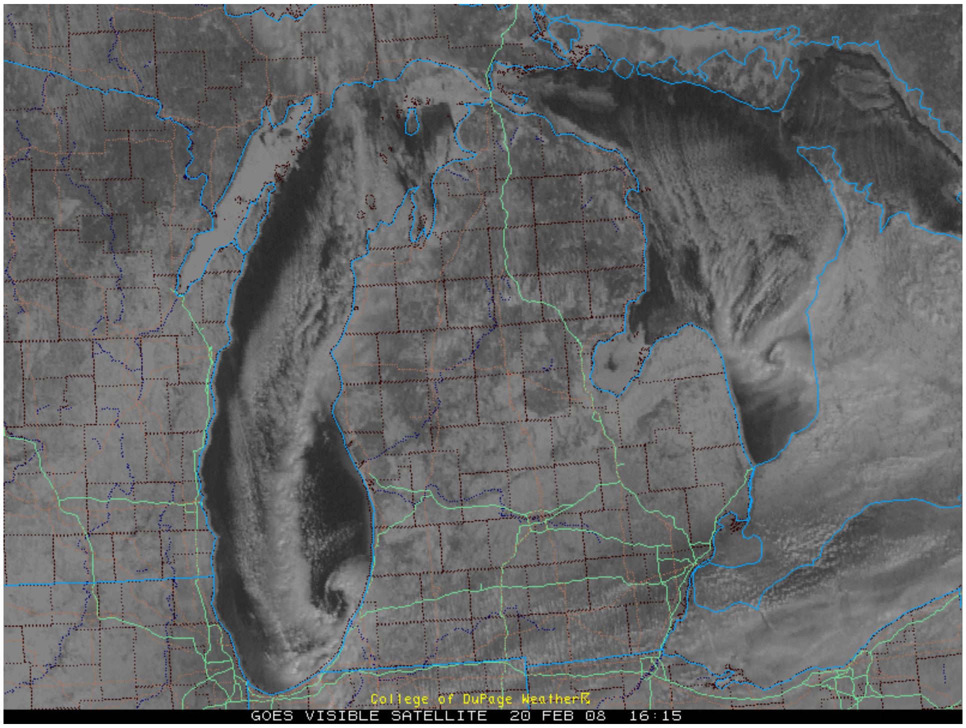

Figure 1. Mesocyclones over southern Lakes Michigan and Huron, 1615Z Feb. 20, 2008 (Image courtesy of College of DuPage)

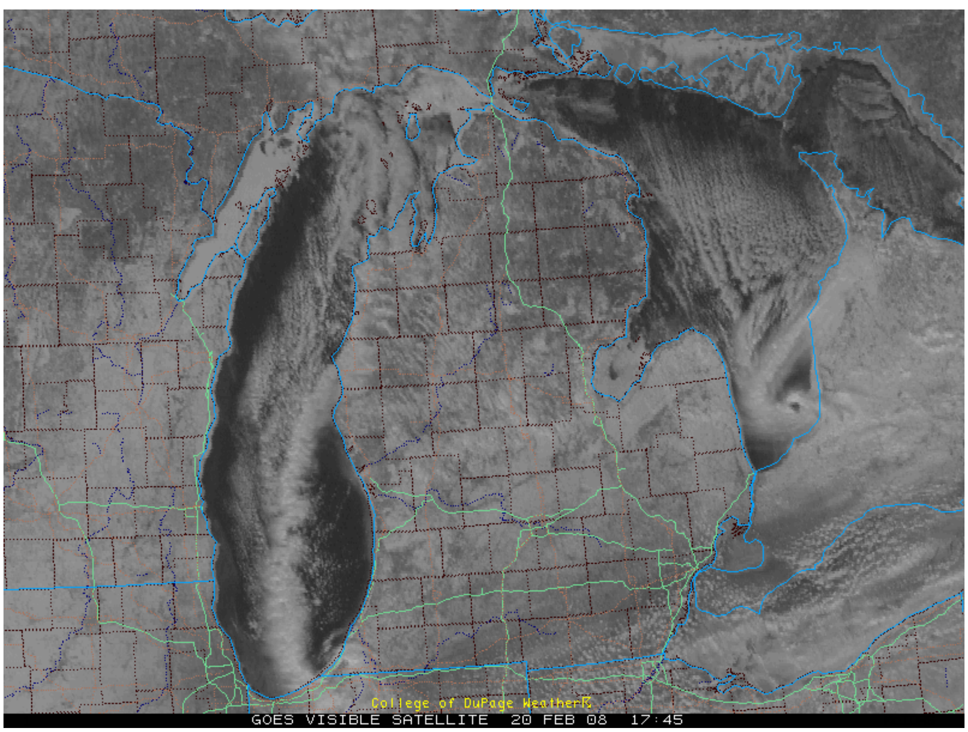

Figure 2. Mesocyclones over southern Lakes Michigan and Huron, 1745Z Feb. 20, 2008, showing some evolution and southward movement during the previous 1 ½ hr (Image courtesy of College of DuPage)

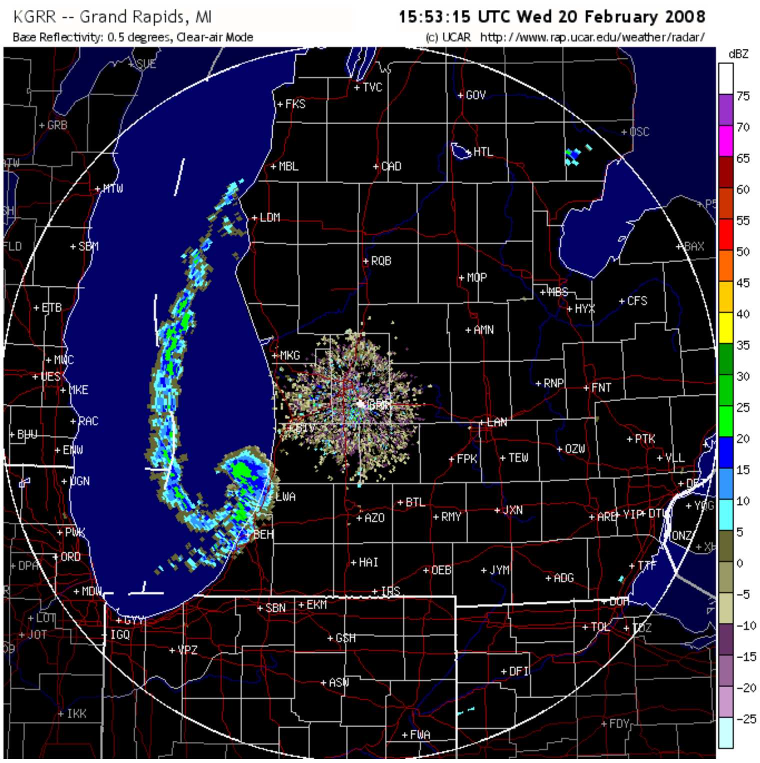

Figure 3. GRR radar reflectivity 1553Z Feb. 20, 2008 showing well-defined precipitation bands coincident with the Lake Michigan mesovortex (Image courtesy of UCAR)

Synoptic Situation

- upper (500 mb) trough moving eastward from the Great Lakes region (Fig. 4)
- 850 mb temperatures near -20 C over the lakes, causing strong instability in the surface-850 layer (Fig. 5)
- surface high pressure region building eastward over the Great Lakes region (Fig. 6)
- subsidence east of the ridge axis, clearing skies (very dry continental Arctic airmass)
- light northerly pressure gradient
- cold air advection (increases instability over the lakes)
- possible cyclonic vorticity advection aloft (may help to lift the low-level inversion enough to allow the lake clouds to grow to sufficient depth for precipitation to develop; with sufficient depth of the mixed layer, latent heat release contributes to cumulus formation)

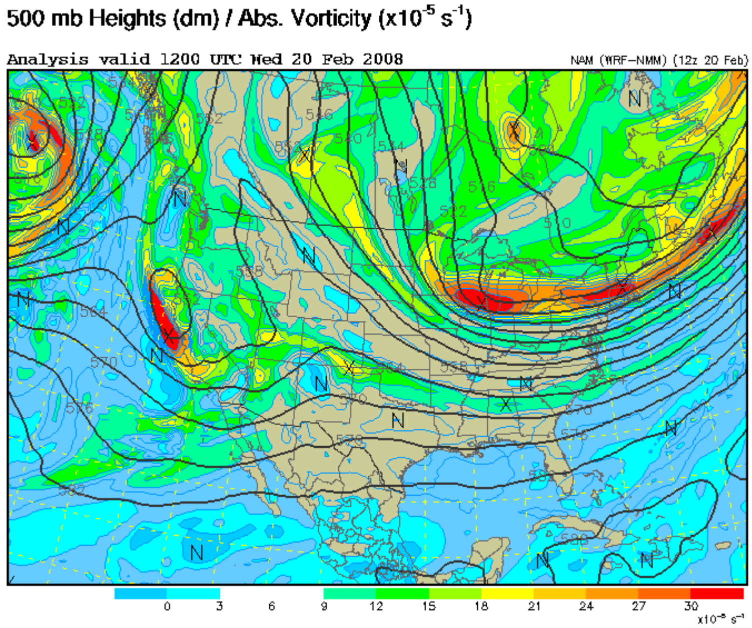

Figure 4. 500 mb height-vorticity analysis, 12Z Feb. 20, 2008 (Image courtesy of UCAR)

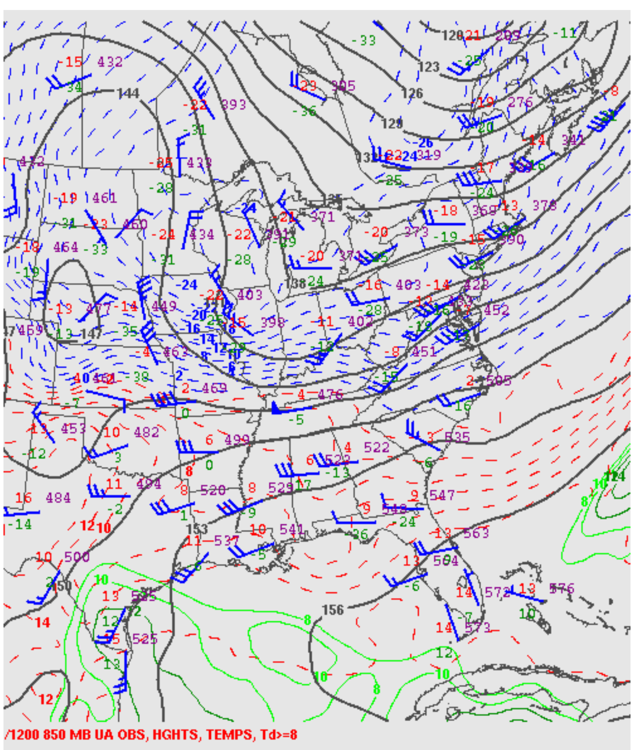

Figure 5. 850 mb height-temperature analysis, 12Z Feb. 20 2008 (Image courtesy of NOAA Storm Prediction Center)

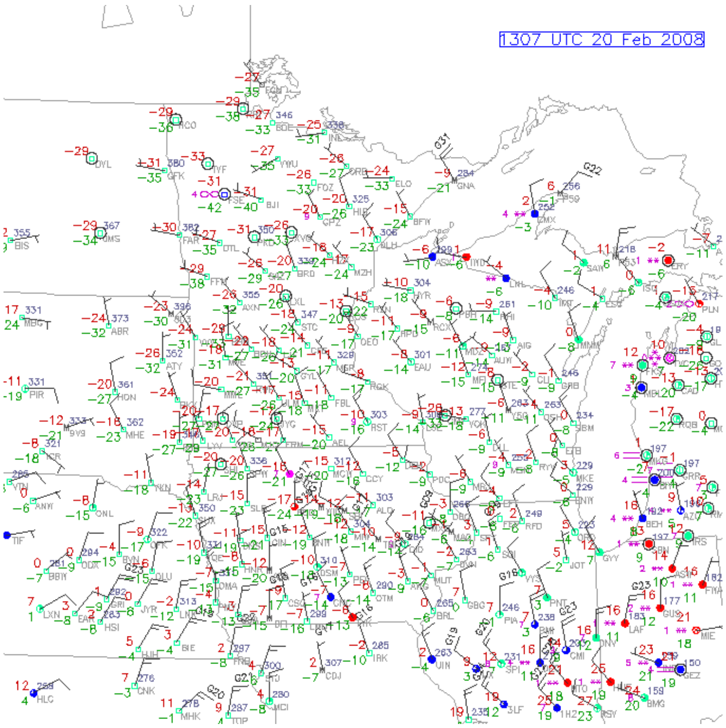

Figure 6. Surface analysis for 13Z (near sunrise) Feb. 20 2008 illustrating frigid land temperatures near Michigan coast (near 0 deg F) and weak pressure gradient, supporting land breeze development (Image courtesy of UCAR)

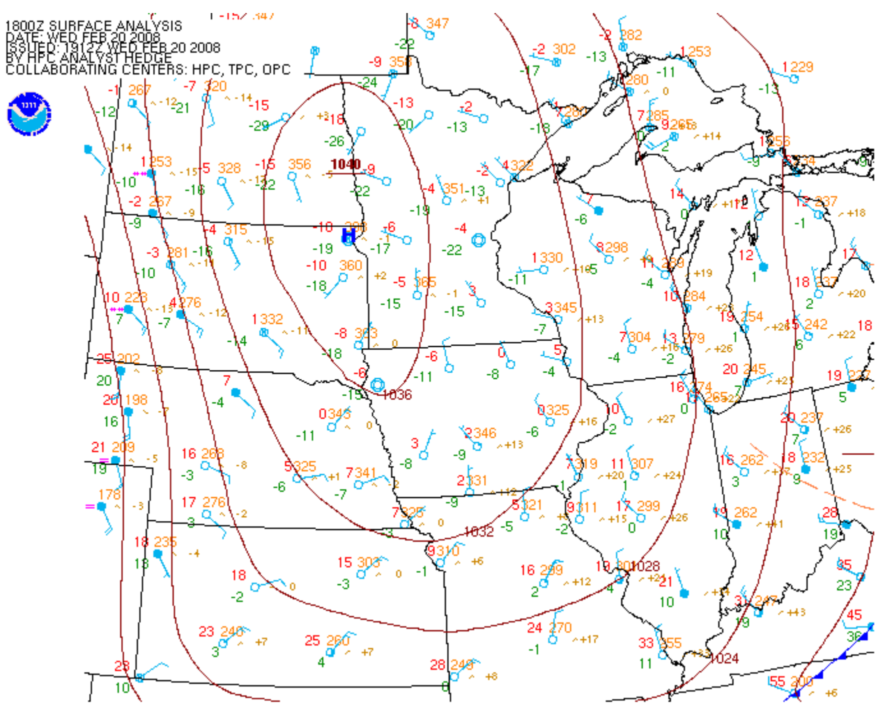

Figure 7. Midwest surface analysis for 18Z Feb. 20 2008 showing location of cA high pressure ridge with light pressure gradient over lakes (Image courtesy of NOAA NCEP)

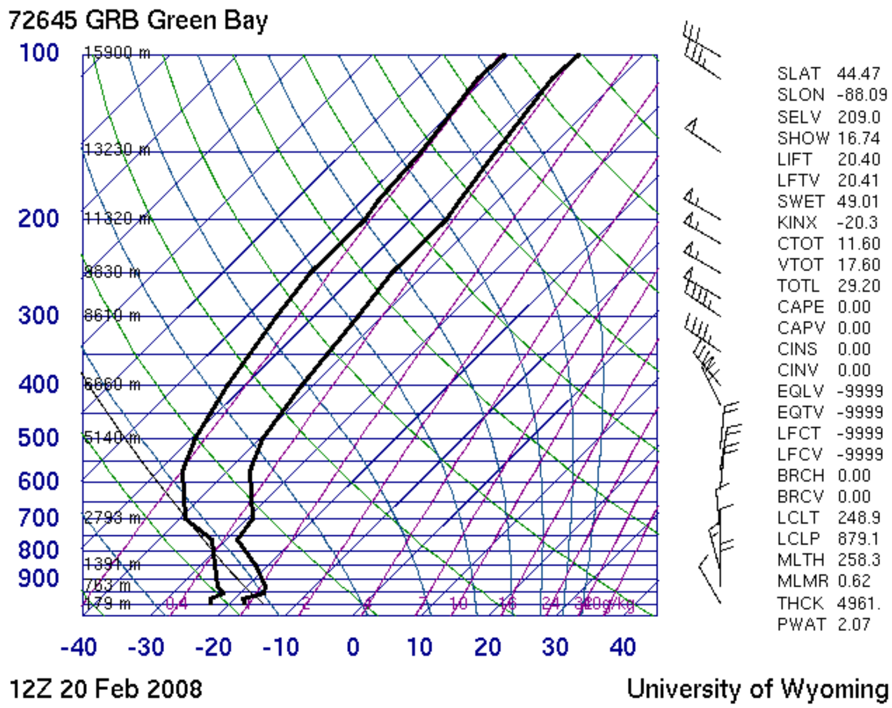

Figure 8. Upper air sounding for Green Bay WI (approx. 50 km west of the Lake Michigan coast) for 12Z shows a subsidence inversion between the 700 and 750 mb levels, and a nocturnal (radiation) inversion below about the 950 mb level (Image courtesy of University of Wyoming)

Effect of Lake Conditions

- unfrozen lakes – allows sensible heat flux from lake water into the overlying cold air, resulting in low-level cloud formation above lake surface. Ice cover exists only on Saginaw Bay (west side of Lake Huron) and Green Bay (west side of Lake Michigan); otherwise, the generally ice-free lakes allowed the maximum vertical flux of sensible heat and moisture
- coastline shape – concave shape near southern sections of Lakes Michigan and Huron contributes to low-level cyclonic circulation when land breezes flow toward the lake. In a study of lake mesocyclones, Forbes and Merritt (1984) found that seven of eight Lake Michigan mesocyclones formed over the southern third of the lake, where coastline curvature is most pronounced

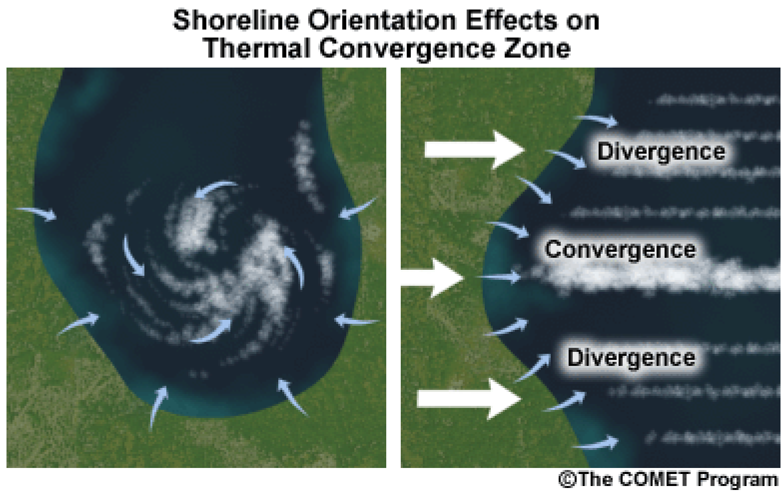

Figure 9. Concave coastline shape contributes low-level cyclonic vorticity to land breeze convergence zones (Image courtesy of COMET)

Effect of Land Surfaces adjacent to Lakeshores

- very cold (snow covered) land surfaces contribute to land breezes during the morning (for coldest land surface temperatures near or shortly after sunrise)
- the temperature contrast between the cold land and the warm, ice-free lake creates thermally-driven land breezes that flow from the cold land surface toward the warm lake surface
- convergence of the land breezes over the lakes promotes the formation of cloud bands and, in this special case, mesovortices

Discussion

- previous studies of lake mesovortices and lake effect cloud processes indicate many interesting factors and details that might be observed
- some sensible weather impacts that may affect populated areas on land include cloudiness, brief snow squalls and gusty winds, and light pressure falls (about 1 mb)
- higher elevation terrain over central Michigan and southern Ontario may contribute to the formation of local, nighttime mesohigh pressure regions, improving conditions for land breezes and drainage flow onto Lakes Michigan and Huron (a study by Schoenberger (1984) indicated that a mesohigh tends to form over the Northern Highlands of Michigan and the cold pool of air contributes to the land breezes flowing westward over the eastern shore of Lake Michigan)
- numerical simulation studies by Pease et al (1988) showed that development does not require support from dynamic features aloft
- a study of co-existing lake mesovortices (Laird, 1999) showed that although synoptic-scale vorticity and thermal advection are not important to development,

these factors may contribute to evolution and propagation of the mesovortices following formation
- in their study of 14 lake mesovortices observed during the years 1978-1982, Forbes and Merritt noted that 57% of the cases studied in their paper showed negative vorticity advection at the 500 mb level during development of the mesovorticies, and only one case showed strong positive vorticity advection

References

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